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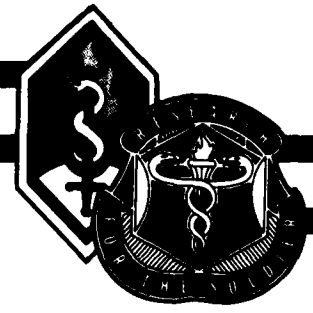

Contact Lens Anterior Surface pH (Reprint)

By

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Sensory Research Division

February 1991

United States Army Aeromedical Research Laboratory
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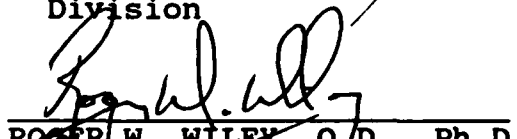

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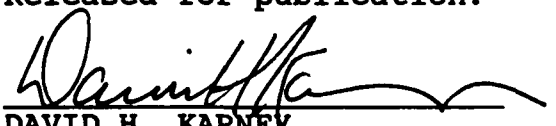

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Clinical Article

Contact Lens Anterior Surface pH

Morris R. Lattimore, Jr., OD, PhD

Recent reports of CO_2 accumulation under hydrogel lenses, paired with the detection of a decrease in stromal pH following contact lens wear, have highlighted the potential for tear pH assessment as a clinical tool. The in situ anterior hydrogel lens surface pH was measured with a flat-surfaced, self-referenced pH electrode in order to indirectly evaluate fluid exchange between the precorneal tear film and hydrogel lenses. Volunteer human subjects were fitted with moderate water content (58%), disposable extended wear hydrogel lenses. Measurements were recorded from the lens in its packaged state (pH 6.99), from the lens in situ 5 minutes after initial lens application (pH 7.17), 24 hours later (pH 7.34), and at the end of 7 days continuous contact lens wear (pH 7.43). Possible cornea-tear film-hydrogel lens interactions could explain certain hydrogel lens-associated contrast sensitivity deficits and transient endothelial changes.

Keywords: Hydrogel contact lenses; tear film pH; extended wear

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Introduction

The anterior corneal surface is associated closely with an overlying canopy of moisture known as the precorneal tear film. Traditionally, clinicians have been concerned with how certain characteristics of the tears can influence corneal integrity; tear film formation problems[1] and tear osmolarity issues[2] represent two examples of purported tear film influence on the cornea. However, the tear film can be susceptible to influence by the cornea, as evidenced by the presence of both glycolytic and tricarboxylic acid cycle enzymes within the tear layer. The source of these enzymes has been shown not to be the lacrimal gland, but, rather, the underlying corneal tissue.[3] Therefore, tear chemistry is affected directly by the cornea. Consequently, clinicians should be reminded that although anatomically distinct the cornea and its tear film are functionally interactive.

Attempts at quantifying the normal tear pH value have yielded varying results. Although one cause of variation appears to be due to instrumentation differences, the primary cause of the variation appears to be the location or source of the tear sample. In the past, the tear film has been approached as a unitary entity independent of whether or not a sample or pH reading was obtained from the fornix, cul-de-sac, inferior meniscus, or limbus. Based on this variety of pH results, shown in *Table 1*,[4-10] it can be concluded that tear pH is location-specific. Discussions stemming from this investigation are limited to the precorneal tear film.

Efforts at documenting the pH of the precorneal tear film (i.e., that canopy of mucin, aqueous, and oil directly anterior to the cornea) have resulted in a mean value range of 7.45 (Ref. 9) to 7.83 (Ref. 10). Since measurements of precorneal tear film pH under the extended open-eye condition (i.e., nonblinking state) have been shown to match

Table 1. Recent Tear pH Studies

Author(s)	Year	Location	Instrument	N (subjects)	Mean ± error
Norn[4]	1988	Inferior fornix	Microglass electrode	41	6.93 ± 0.24
Coles and Jaros[5]	1984	Lateral fornix	Direct contact microelectrode	133	7.11 ± 1.50
Fischer and Wiederholt[6]	1982	Limbus (1 o'clock) Limbus (5 o'clock)	Micro-pH electrode Micro-pH electrode	4 4	7.60 ± 0.09 7.50 ± 0.08
Abelson et al.[7]	1981	Inferior cul-de-sac	Microcombination glass pH probe	44	7.00 ± 0.20
Andres et al.[8]	1988	Precorneal	Micro-pH electrode	71	7.51 ± 0.18
Carney and Hill[9]	1976	Meniscus	Microelectrode	16	7.45 ± 0.16
Chen and Maurice[10]	1990	Precorneal	Fluorescent probe	6	7.83 ± 0.10

that predicted by CO_2 cornea-tear film equilibration calculations,[6] it is likely the above values are very close to the true precorneal tear film pH.

Initial research indicated hydrogel contact lenses may provide a barrier to carbon dioxide (CO_2) efflux from the cornea, although at the time this was considered to be insignificant in terms of corneal physiology.[11] However, recent measurements of tear CO_2 accumulation under hydrogel lenses,[12] paired with the detection of a decrease in both subcontact lens[10] and stromal pH following contact lens wear,[13] indicates yet another functional link between the precorneal tear film and corneal physiology. Indeed, Holden et al.[12,14] have tied the issues of subhydrogel lens CO_2 accumulation and tissue pH changes to the endothelial bleb response. Since the issue of anterior segment CO_2 expiration has been associated with one aspect of the precorneal tear film (i.e., the subcontact lens tear film), it is possible other aspects of the precorneal tear film may be influenced as well. The purpose of this study was to evaluate fluid exchange interactions between hydrogel lenses and the precorneal tear film in an attempt to indirectly monitor corneal and subcontact lens pH changes resulting from hydrogel contact lens wear.

Materials and Methods

A self-referenced pH electrode (Orion Research, Model SA 230), designed for pH recording from semisolid materials, was used to assess the in situ anterior contact lens surface pH response to continuous wear of a 58% water, disposable soft contact lens. The recorded pH reading was the peak value of a transient response. Upon initial probe application, the measured pH value was within 0.2 of the final or peak value. However, a gradual drift in the alkaline direction led to stabilization of the reading, presumably due to temperature changes at the probe surface. If the probe was kept in contact with the lens beyond the stabilization period, a gradual shift in the acidic direction was noted. This has been attributed to CO_2 accumulation under the probe (Fatt, personal communication).

Subjects were on a 1-week wearing cycle, after which time the lenses were removed, disposed of, and replaced after at least one night of lens-free sleep. The pH electrode was calibrated with a 7.00 and a 10.00 pH standard solution at 35°C and disinfected by alcohol swab and surface drying between each assessment. Probe calibration was then maintained at 35°C. Measurements were recorded from the contact lens in its storage packet immediately after opening, then 5 minutes after initial lens application onto the volunteer subject's eye, 24 hours after initial lens application, and 7 days after initial lens application. Additional anterior lens surface pH recordings were made during the course of follow-up examinations after 1, 3, and 6 months of contact lens-wearing experience using the weekly wearing paradigm detailed above. Each measurement for any one individual was taken at the same time of day in order to minimize error from individual diurnal variations.[9] However, pH assessments across individuals occurred at varying times of day, thereby eliminating any group diurnal effect.

Results

Figure 1 provides a graphical data representation. The contact lens in solution is very near a neutral pH of 7.00. Within the first 5 minutes of contact lens wear, the pH reading started to rise into the alkaline region (7.17); a further increase in pH is noted after 24 hours of wear (7.34). Stabilization of pH (7.43) is apparent at day 7 near established norms for the nonlens-wearing precorneal tear film. Subsequent pH measurements after 1, 3, and 6 months of weekly disposable contact lens wear fall between the pH values found on day 1 and day 7 (7.38). Baseline, 5-minute, and 24-hour data are statistically significant by the t-test ($p < 0.05$). Subsequent measurements (7 day and 1-, 3-, and 6-month follow-ups) are not statistically different from the 24-hour pH value ($p > 0.20$). However, an analysis of variance (ANOVA) over the 1-week initial period elicits a statistically significant trend for pH shift over the entire initial 7-day time period.

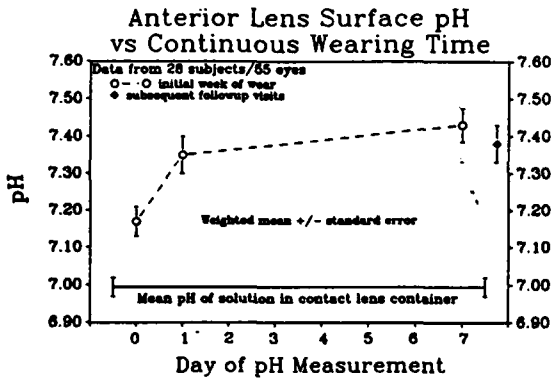

Figure 1. Anterior lens surface pH vs. continuous wearing time.

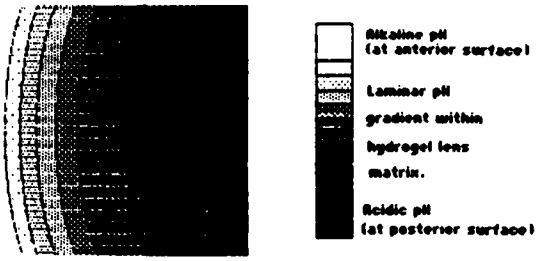

Figure 2. The graphic represents the proposed pH gradient that could be present within the in situ hydrogel lens matrix as a result of carbon dioxide accumulation. This pH gradient, in turn, would reflect the presence of underlying water content and refractive index gradients as well.

Discussion

The initial in situ pH reading of 7.17, taken just 5 minutes after lens application, suggests that a fluid exchange between the anterior tear film and the contact lens occurs very quickly. However, pH values obtained on subsequent follow-up evaluations (1, 3, and 6 months postfitting) documented the pH status of lenses that had been worn 2–7 days prior to those pH measurements. Since the average long-term follow-up pH value (7.38) falls between the initial week's pH values for day 1 (7.34) and day 7 (7.43), it would be reasonable to accept the concept of a long-term pattern of fluid exchange reaching equilibrium somewhere within a 7-day range of hydrogel lens wear. It should be noted here that the use of this pH electrode methodology assumes the anterior contact lens surface pH measurement accurately represents both the prelens tear film pH and the pH of the anterior water component of the hydrogel contact lens. However, it is possible these two entities could have slightly different pH values.

The final pH data for day 7 of the initial week of lens wear are not much different from the accepted published norms for the precorneal tear film.[6,9] The initial data (days 0 and 1) are less alkaline compared to precorneal tear film norms, possibly due to the starting lens pH of 7.00; if the lenses were packaged in a storage solution of a more alkaline nature near 7.45, this pattern of pH adjustment might not be exhibited. In any event, the data do not support the use of this system as a useful indirect monitor of corneal and subcontact lens pH changes related to hydrogel lens wear. However, it may be possible to estimate CO_2 expiration rates by monitoring the anterior lens surface pH over a lengthy continuous probe application period. In future studies, the combined knowledge of CO_2 expiration rates and O_2 uptake rates might provide clinically useful information.

Accepting previous reports of pH decrease/CO_2 trapping or buildup under hydrogel lens,[10,12,14] it is possible that a pH gradient exists within the matrix of a hydrogel lens (Figure 2). Moreover, this gradient, bordered by different pH environments at each hydrogel lens surface, would preclude a lens from being considered as simply a unitary piece of plastic. It previously has been shown that soft lens hydration is directly influenced by the pH of its solution.[15] Therefore, a lens in close approximation with a cornea, with differing pH solutions at each surface, could have a transitional water content from one surface to the other. Consequently, there would be a varying index of refraction as well. This pH gradient then would create layers of "lenses" between the physical confines of the anterior and posterior lens surfaces. This laminar arrangement of varying water content and refractive indices could be responsible for the optical issues linked to certain contrast sensitivity deficits of hydrogel lens wear.[16–18]

Lastly, is the initial, packaged lens pH significant to the physiological integrity of the cornea? It is accepted that the maintenance of corneal thickness and transparency, by way of active ion transport, is pH dependent.[19] In addition, induced relative acidic pH changes at the level of the endothelium have been linked to the transient endothelial bleb response.[12,14] Finally, a number of possible effects of an acidic shift in the cornea have previously been suggested.[20] Therefore, it is not unreasonable to suggest that the application of a moderate- to high-water-content hydrogel lens of a 7.0 pH or lower, weighing approximately 0.013 g, holding roughly 7.5 µl of water (if a 58% water material), would immediately create a stressful environment for the cornea. Within the context of this study (58% water content lens), application of a hydrogel lens to the anterior surface of the cornea effectively doubles the volume of fluid anterior to the cornea, since the typical precorneal tear film is 7–8 µl in volume. If the lens matrix possesses a pH that is relatively acidic compared with the precorneal tear film norm, then a significant metabolic challenge could be presented to the cornea proper. The pH-mediated transient endothelial bleb response could therefore be a reflection of this initial challenge. Upon initial lens application, the pH-induced stress would be at a peak and then begin to decline as the water component slowly equilibrates with the tear film. However, concurrent CO_2 expiration and trapping would elicit a supplementary pH-induced stress. With

the endothelial bleb response being related to pH challenge, it is reasonable to conclude that the application of a hydrogel lens, exhibiting pH characteristics relatively acidic compared with the normal precorneal tear film, is the trigger for hydrogel lens-related transient endothelial changes. If this untested hypothesis is valid, then immediate, transient endothelial changes (i.e., the bleb response) could be bypassed by packaging hydrogel lenses at a slightly alkaline pH.

In summary, simple pH measurement of the anterior lens surface does not appear to provide clinically useful information, although a pH profile monitored over an extended time period may provide information concerning CO_2 expiration. A number of questions can be raised concerning both the susceptibility of visual performance and corneal physiology to external influence by the physical state of the hydrogel material when placed on the cornea.

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References

1. Grayson M: Diseases of the cornea. St. Louis, C.V. Mosby, 1983, pp 339–343.
2. Farris RL, Gilbard JP, Stuckell RN, Mandel ID: Diagnostic tests in keratoconjunctivitis sicca. *CLAO J* 1983;9:23–28.
3. Fullard RJ, Carney LG: Diurnal variation in human tear enzymes. *Exp Eye Res* 1984;38:15–26.
4. Norn MS: Tear fluid pH in normals, contact lens wearers, and pathological cases. *Acta Ophthalmol* 1988;66:485–489.
5. Coles WH, Jaros PA: Dynamics of ocular surface pH. *Br J Ophthalmol* 1984;68:549–552.
6. Fischer FH, Wiederholt M: Human precorneal tearfilm pH measured by microelectrodes. *Graefes Arch Ophthalmol* 1982;218:168–170.
7. Abelson MB, Udell IJ, Weston JH; Normal human tear pH by direct measurement. *Arch Ophthalmol* 1981;99:301–304.
8. Andres S, Garcia ML, Espina MM, Valero J, Valls O: Tear pH, air pollution, and contact lenses. *Am J Optom Physiol Opt* 1988;65:627–631.
9. Carney LG, Hill RM: Human tear pH. *Arch Ophthalmol* 1976;94:821—824.
10. Chen FS, Maurice DM: The pH in the precorneal tearfilm and under a contact lens measured with a fluorescent probe. *Exp Eye Res* 1990;50:251–259.
11. Fatt I, Bieber MT, Pye SD: Steady state distribution of oxygen and carbon dioxide in the *in vivo* cornea of an eye covered by a gas-permeable contact lens. *Am J Optom Arch Am Acad Optom* 1969;64:3–14.
12. Holden BA, Ross R, Jenkins J: Hydrogel contact lenses impede carbon dioxide efflux from the human cornea. *Curr Eye Res* 1987;6:1283–1290.
13. Bonano JA, Polse KA: Effect of contact lens wear on stromal pH. *Am J Optom Physiol Opt* 1986;63:58–62.
14. Holden BA, Williams L, Zantos SG: The etiology of transient endothelial changes in the human cornea. *Invest Ophthalmol Vis Sci* 1985;26:1354–1359.
15. McCarey BE, Wilson LA: pH, osmolarity, and temperature effects on the water content of hydrogel contact lenses. *Contact Intraoc Lens Med J* 1982;8:158–167.
16. Woo GCS, Hess RF: Contrast sensitivity function and soft contact lenses. *ICLC* 1979;6:171–176.
17. Bernstein IH, Brodrick J: Contrast sensitivity through spectacles and soft contact lenses. *Am J Optom Physiol Opt* 1981;58:309–313.
18. Grey CP: Changes in contrast sensitivity during the first hour of soft lens wear. *Am J Optom Physiol Opt* 1986;63:702–707.
19. Fischer FH, Weiderholt M: The pH dependency of sodium and chloride transport in the isolated human cornea. *Invest Ophthalmol Vis Sci* 1978;17:810–813.
20. Efron N: The greenhouse effect and contact lenses, in *Transactions of the British Contact Lens Association Conference*, 1989, p. 7.

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